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TECHNICAL NOTE

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ARCTIC METEOROLOGY PHOTO PROBE POLARIZED LIGHT EXPERIMENT (Continuation of Project AMPP)

by

Gerald L. Hempfling, Harold E. Evans,
Robert C. Baumann, and Richard J. Andryshak
Goddard Space Flight Center
Greenbelt, Maryland

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SUMMARY

Two Aerobee-100 rockets were launched from Fort Churchill, Manitoba, Canada during May 1961. The program objectives were:

1. To obtain high-altitude photographs of cloud formations with a snow and ice underlay to determine the effectiveness of a polarizing filter in distinguishing clouds from snow and ice.

2. To compare pictures taken from the same altitude, with and without a polarizing filter, to establish the degree of polarization taking place.

3. To determine whether snow, clouds, and ice could be distinguished readily from *un*polarized high-altitude black and white photographs.

High-altitude pictures were obtained which illustrated the polarizing effects of ice crystals. At certain polarization angles ice, snow, and clouds are clearly distinguishable. Ice, snow, and clouds also could be distinguished on properly exposed unpolarized black and white photographs although the distinction was not as clear as on the polarized photographs.

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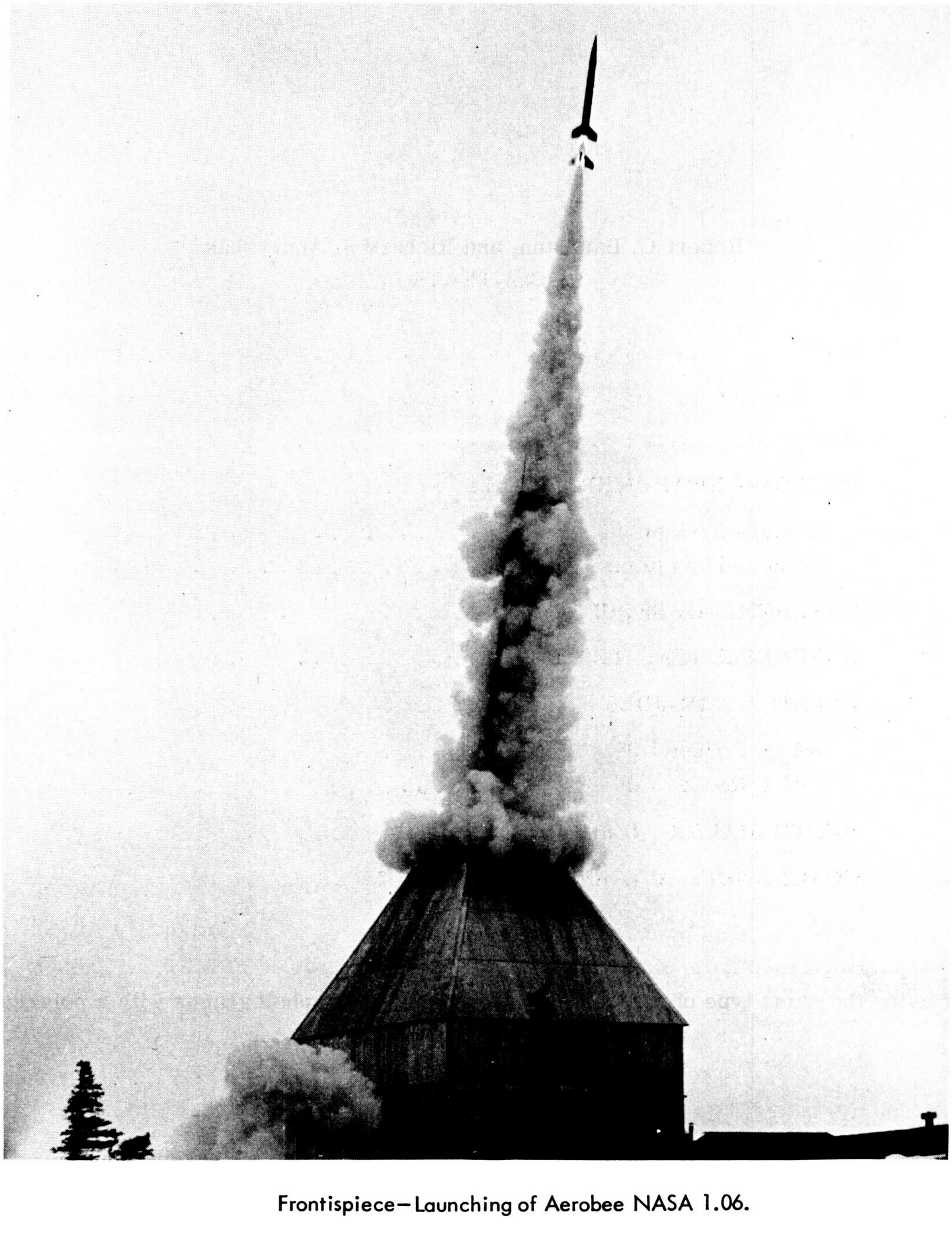

Frontispiece—Launching of Aerobee NASA 1.06.

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INTRODUCTION

As a continuation of the Arctic Meteorology Photo Probe (AMPP) program*, two Aerobee-100 rockets were launched in May 1961 from Fort Churchill, Manitoba, Canada. The experiment flown was quite similar in nature to the previous AMPP program experiment but with the added objective of obtaining polarized and unpolarized photographs of cloud cover over ice and snow.

Proper evaluation of data from meteorological satellites that pass over polar regions will require that it be possible to distinguish between ice, snow, and various types of clouds. Although resolution of such pictures obtained at present is good, it is not good enough to enable the viewer to pick out these differences from a transmitted picture. The AMPP polarized light experiment was flown to investigate the possibility of using polarization techniques to add in distinguishing between ice, snow, and various types of clouds.

In general, reflected light from ice crystals is polarized, to a certain degree, while the reflected light from clouds is unpolarized. Hence, if the polarizing effect can be photographed, white clouds can be distinguished from snow and ice. Results from previous AMPP launchings* prompted the idea of using the same type of payload to obtain high altitude photographs with a polarizing filter. Three of the original AMPP structures, two of which had been flown and recovered, were rewired and fitted with new components for use in this experiment (Figures 1, 2, and 3).

In addition, two nuclear emulsion packages to study high-altitude radiation were added to the payload system (Figure 4); the data or results obtained by the emulsion packages will not be presented here.

*Evans, H. E., Baumann, R. C., and Andryshak, R. J., "The Arctic Meteorology Photo Probe," NASA Technical Note D-706, February 1962.

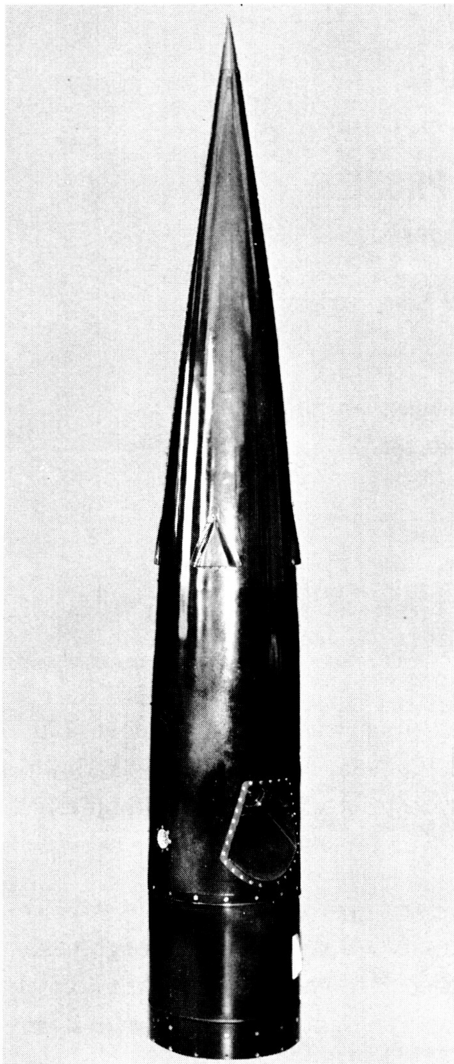


Figure 1—Typical AMPP Payload.

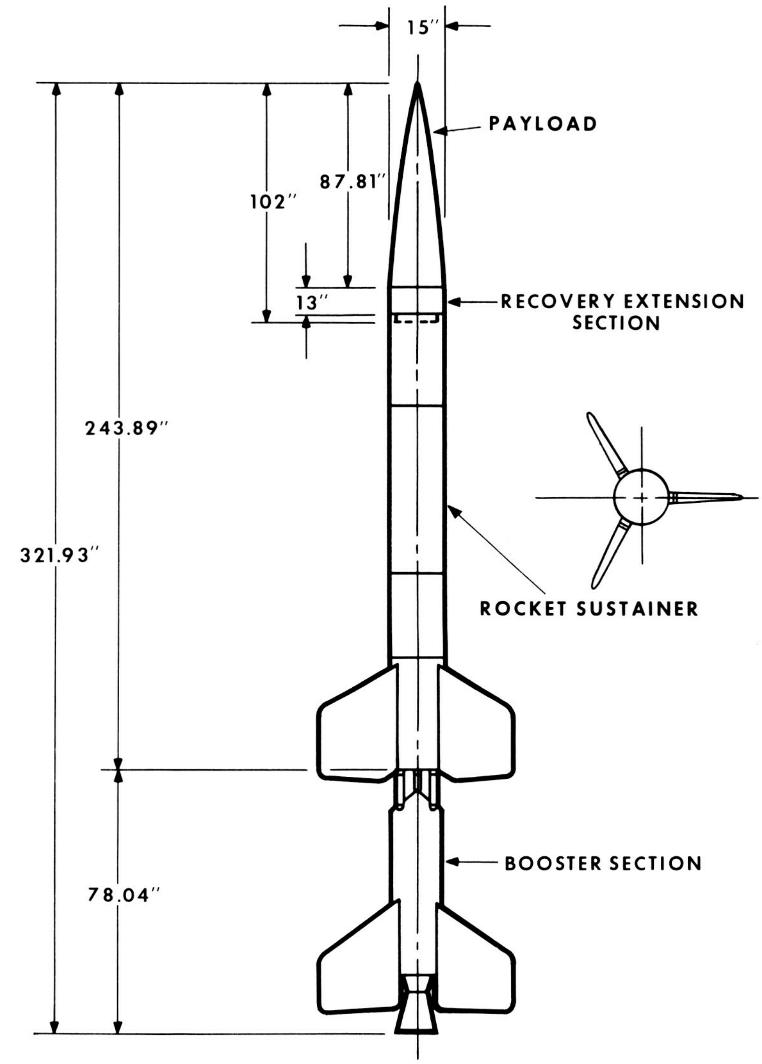


Figure 2—Outline of the Aerobee-100 rocket.

The only Aerobee launch site with the desired meteorological conditions which coincided with the scheduled completion date of payloads was located at Fort Churchill (the snow and ice remain until around the middle of May).

A 50 percent random type cloud cover with the edge of a front moving in from the West was the most desirable type of weather conditions to be photographed. Also, the optimum time of day for taking the photographs was between 8:00 a.m. CST and 4:00 p.m. CST; this insured adequate sun illumination of ground and clouds.

The major program requirement was that pictures be taken with at least two cameras—one with a polarizing filter on the lens and one without. To meet the program requirements, assurance was needed that both cameras would function; this necessitated a redundant system design.

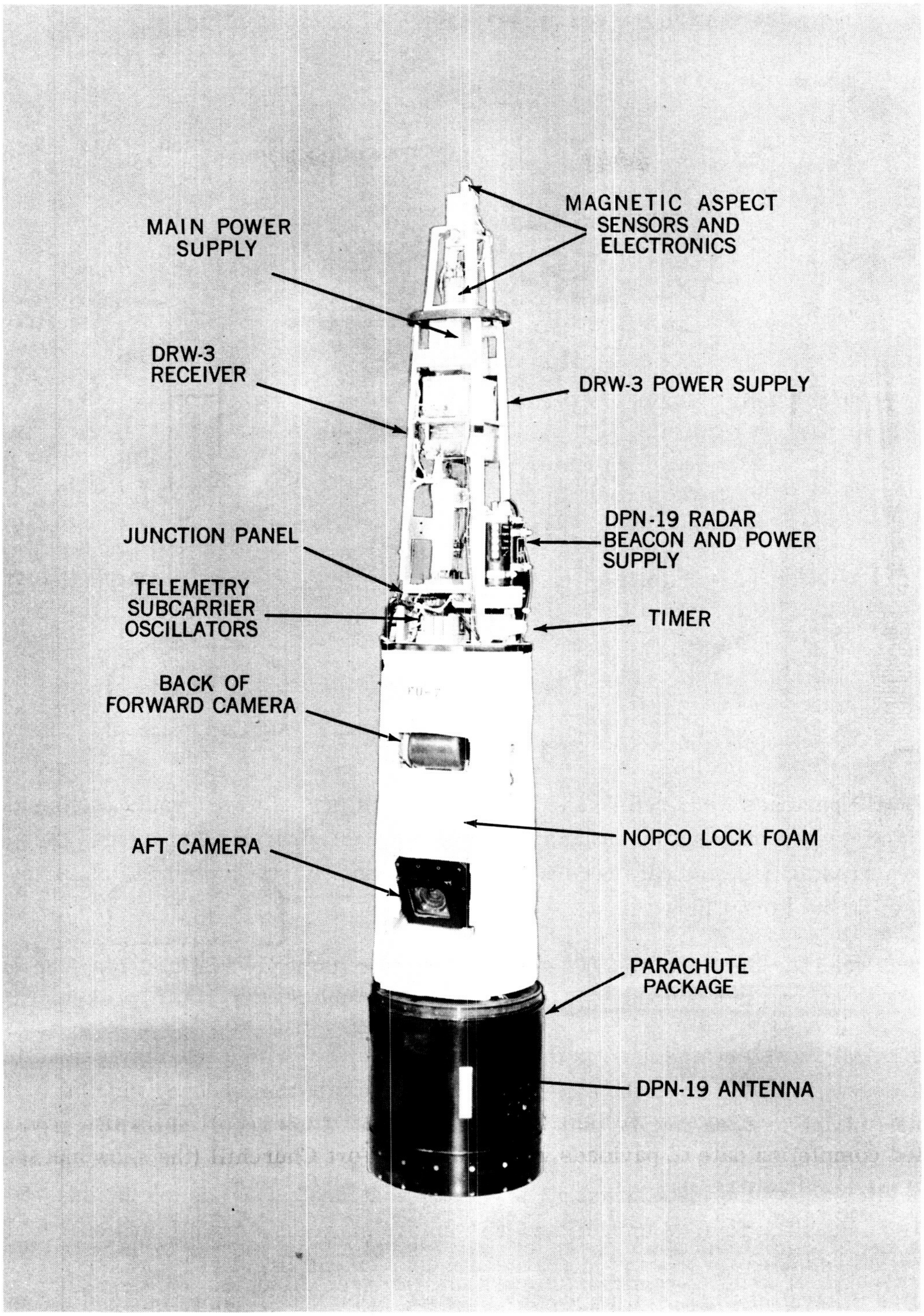


Figure 3—Payload Instrumentation.

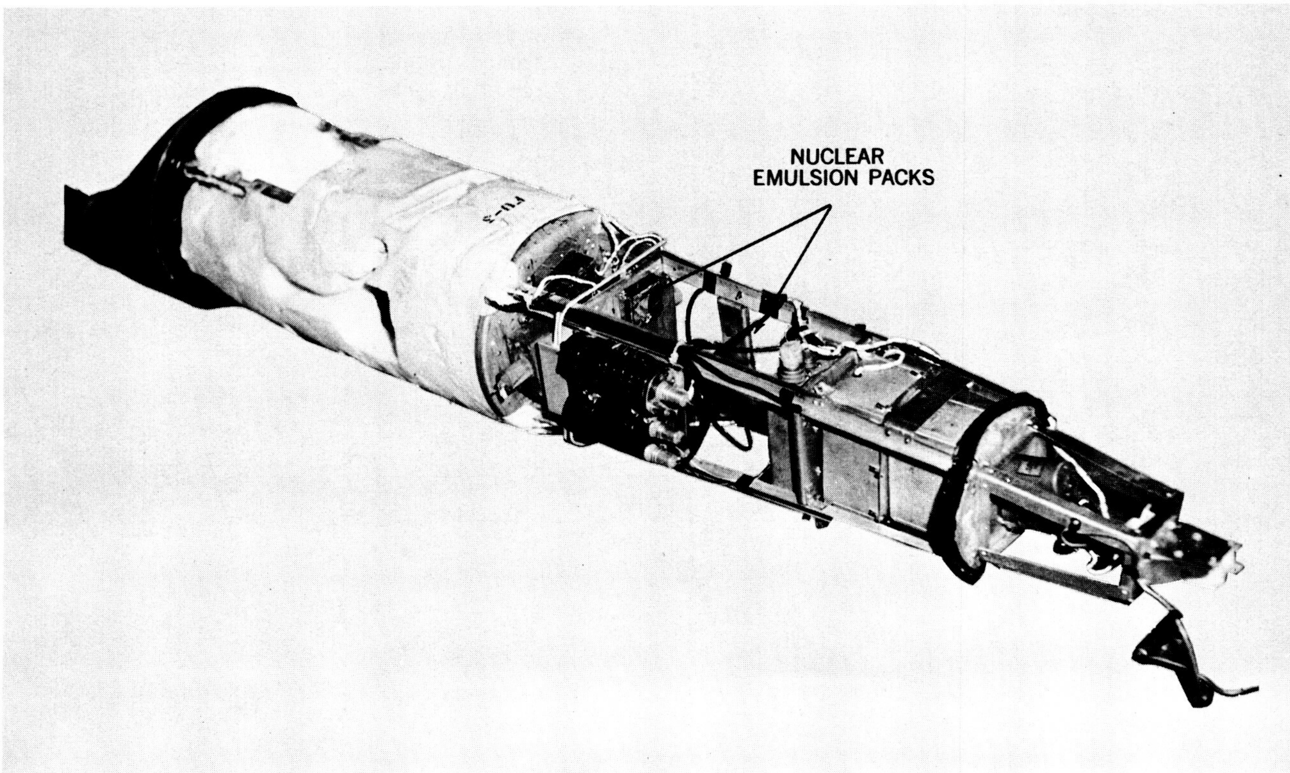


Figure 4—Recovered payload from NASA Rocket 1.06.

Three AMPP payloads were refurbished for these tests, one of which would be considered a back-up unit in the event of insufficient data from either of the first two launchings. Support facilities for launching, tracking, and data recovery were provided by the United States Army Rocket Research Facility at Fort Churchill.

The launch vehicle, the Aerobee-100, was selected for its ready availability. The trajectory (Figure 5) was based on the previous AMPP firings of the same rocket, NASA Rockets 1.03 and 1.05*.

The basic AMPP system was used in this payload (Figure 3) with a few minor modifications. The hot pins were eliminated from the pull-away plug because of the tendency for pins to short against the shell when making or breaking the pull-away connection. This required that the payload batteries be charged prior to installation into the payload because the hot pins had been essential in charging the batteries after nose cone installation. The "water switches", used as one method for triggering the parachute cutoff after payload impact, and both smoke markers were eliminated. Additional aneroid switches were added for arming the parachute detachment circuitry. The two program timers were connected in parallel so that either would cause operation of both cameras. A slight modification was also made to the waterproof camera case so that two filters could be installed on the cameras. The rocket spin rate desired during camera operation was between 0.2 and 0.4 rps; the actual spin rate achieved was approximately 0.36 rps.

*Ibid.

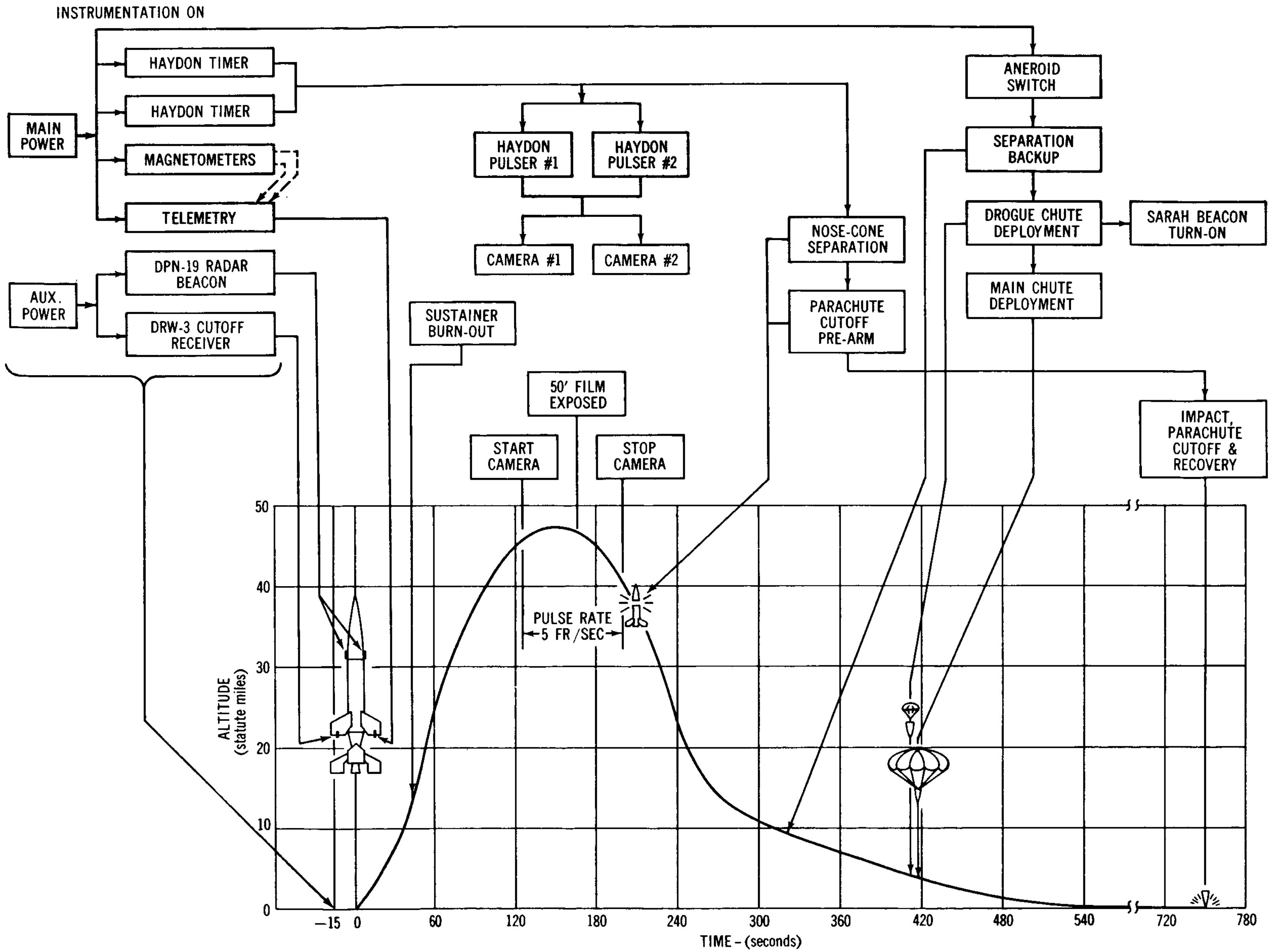


Figure 5—AMPP operational sequency and Aerobee-100 predicted trajectory.

It was desirable to have an aerodynamically unstable vehicle during camera operation so that numerous "look" angles could be achieved of the same subject; this would cause the polarizing axis of the camera filter to be orientated at various angles with the axis of the polarized light from the subject. As it happened, very few look angles were attained because the payload rocket combination proved to be very aerodynamically stable.

PAYLOAD INSTRUMENTATION

Camera Systems

Each payload carried two Maurer model 220 70-mm aerial cameras (Figures 3 and 6) mounted 180 degrees apart and aimed 30 degrees down from the horizontal in such a manner that, with a vertical attitude, all pictures would include the horizon. Each camera carried approximately 50 feet of film, or approximately 230 frames.

To obtain the greatest field of view, both cameras were programmed to operate during the period when the payload was at the peak of the trajectory (Figure 5). The cameras were pulsed at 5 frames per second.

Both cameras contained type SO 136 Kodak Experimental Panatomic-X Aerographic film (black and white). One camera contained a No 12 filter and a polarizing filter while the other camera contained only the No 12 filter. Exposure settings and filters were recommended by the Eastman Kodak Co. Research Laboratories. The No 12 filter was received through J. A. Maurer, Inc., and the polarizing filter (105 PB) was received from Polacoat, Inc.

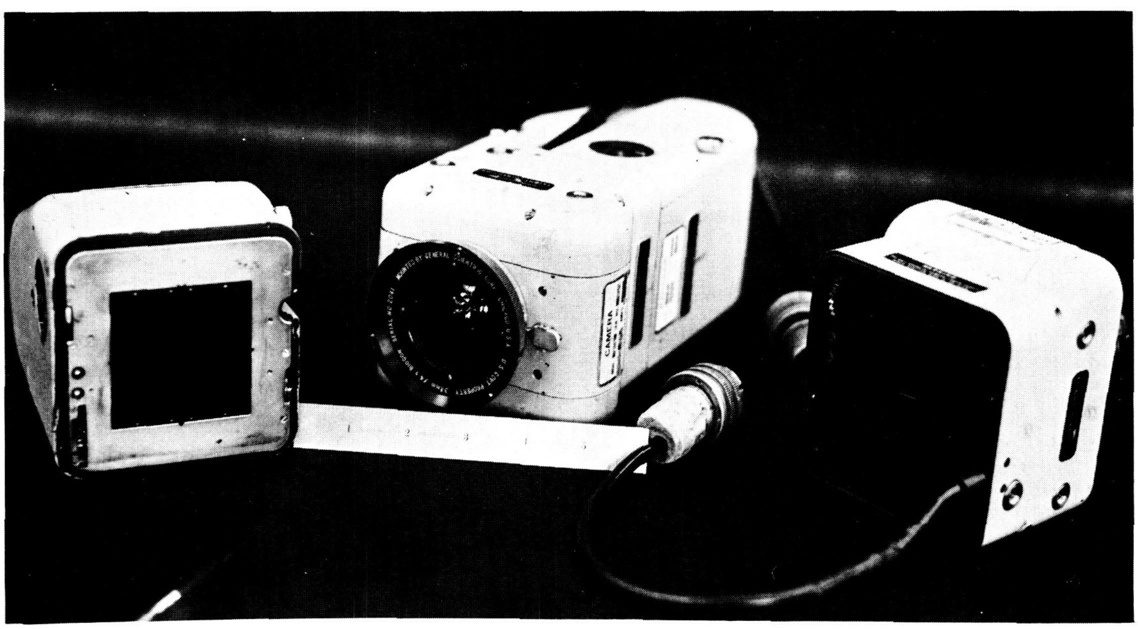


Figure 6—Maurer model 220 70-mm aerial camera.

Electronic Systems

Each payload carried a four-channel FM-FM telemeter (Figure 3) consisting of a 227.5-Mc transmitter, a subcarrier mixer, an amplifier, a voltage regulator, and four voltage-controlled oscillators (VCO's). The VCO frequencies were IRIG bands 9G, 10G, 11G, and 13G. A notch antenna for telemetry transmission was located on one of the rocket fins. Vehicle aspect and camera actuation data were telemetered.

The rocket aspect with respect to the magnetic field of the earth was determined by two fluxgate magnetometers (Figure 3). These were mounted on the forward shelf of the payload and oriented at right angles to each other, with one in line with the spin axis of the payload.

A DPN-19 radar tracking beacon (Figure 3) was used for both range safety tracking and overall trajectory tracking. Both the beacon and its antennas were mounted in the payload itself to permit continuous tracking of the payload from liftoff to impact. A DRW-3 cutoff receiver (Figure 3) was used in conjunction with the DPN-19 as part of the range safety system. It was electrically wired to a detonator block positioned to cut the fuel line, should range safety require flight termination.

A SARAH* beacon was used to facilitate payload recovery. Activated at the time of parachute deployment, the beacon was designed to broadcast a 243-Mc signal continuously for approximately 20 hours.

Electrical power was supplied by one main battery pack consisting of 20 Yardney HR-3 silver cells and two auxiliary battery packs containing 10 HR-3's and five HR-1's.

Payload master programming was controlled by two Type 3614 programmers manufactured by the A. W. Haydon Co. The cameras were pulsed by two A. W. Haydon Type 3613 pulsers.

OPERATIONAL SEQUENCE

A graphic representation of the sequency of events contrasted against flight stage is shown in Figure 5. Table 1 shows the programming.

The camera programming was the same for both payloads. Camera programming was provided by two motor-driven Haydon master timers which began operations simultaneously at T - 15 seconds when the launch switch on the monitor panel was thrown. At predetermined points in the trajectory the two master timers, each by closing its Switch S_1, actuated two pulse timers which pulsed the cameras at a rate of 5 pulses per second.

TABLE 1

Payload Programming

Time (sec)	Approximate Altitude	Event
0	0 st mi	Booster Ignition
0	0 st mi	Sustainer Ignition
2.5		Booster Burn-out
2.5		Booster Separation
41	16 st mi	Sustainer Burn-out
123	45 st mi	Start Cameras
151	45.4 st mi	Apogee (estimate)
198		Stop Cameras
218		Payload Separation & Parachute Release Pre-arm
	20,000 ft	Parachute Deployment
	3,000 ft	Power to Inertia & Altitude Sws.
	0 st mi	Impact & Parachute Release

*From Search And Rescue And Homing. A video homing device originally designed for personnel rescue and now used in capsule recovery operations at sea.

The two master timers differed in that Switch S_1 closed at 138 seconds on one and at 153 seconds on the other; each stayed closed for 60 seconds*. Since the two S_1 switches were connected in parallel for reliability purposes, this gave the camera pulse timers an operating period between 138 seconds and 213 seconds, or a total pulse time of 75 seconds for each camera. In both launches, the timers were started 15 seconds prior to launch giving an operating period of T + 123 seconds to T + 198 seconds during the rocket trajectory. Actual picture-taking occurred during the first 45 seconds of operation, and 30 seconds were left to take care of overruns, hung film, etc.

The pulse timers provided voltage signals to operate the two camera motors. These voltages were telemetered, and the received information provided a means of time-matching the photographs with corresponding altitude and magnetometer aspect data.

During descent, the payload was programmed to separate from the rocket sustainer at T + 218 seconds. This separation was accomplished by detonation of primacord when the separation switch in the master programmers closed. The primacord was located in a groove about the inside diameter at the interface surface between the parachute pack and the rocket sustainer. Four "H"-connected 20,000-foot-altitude aneroid switches were connected in series with the separation switch, thereby protecting against separation on the upward leg of the trajectory. These aneroid switches were in the open position at altitudes below 20,000 feet. The "backup" to the master program timer for accomplishing separation was provided by two parallel-connected 50,000-foot-altitude aneroid switches; these were in the open position at altitudes below 50,000 feet. When that altitude was attained during rocket ascent the switches closed, energizing a snap action relay and a latching relay. Both relays remain energized, but power did not flow until the switches reopened below 50,000 feet on the downward leg. At that time the snap action relay opened and the latched relay remained closed; in this condition, power was transferred through the latched relay, through the 20,000-foot-altitude switch bank, and to the separation detonator block.

The parachute was programmed to deploy at 20,000 feet altitude, at which point the SARAH beacon began operating. Upon impact with land or water, the parachute detached itself and the SARAH beacon continued transmitting. In water, the payload would float nose down with about 20 inches showing above the surface.

ENVIRONMENTAL TESTING

Since these payloads were similar to the previous AMPP payloads, only a flight acceptance test program was performed.

The sequence of testing consisted of: a static operational test of the payload system, and axial flight vibration test, another static operational test, and finally an operational test during which the payload was spinning about its longitudinal centerline. Several minor system malfunctions were disclosed during these tests. The payloads were retested after the malfunctions were corrected.

*These particular times were necessary on the previous AMPP payloads, and due to the availibility of this type of timer, it was also used on this program.

During the vibration test, the payload was attached to a vibration test fixture in a manner which simulated the actual mounting to the rocket, and vibrated in a vertical direction with the spin axis vertical. Vibration limits in the axial direction were as follows: frequency from 20 to 2000 cps; spectral density of 0.05 g^2/cps; duration 60 seconds. Maximum double amplitude was 0.4 inch (0.05 g^2/cps at 10 g rms).

FLIGHT SUMMARIES

NASA Rocket 1.04

The AMPP payload designated as Flight Unit 6 was flown on NASA Rocket 1.04. The rocket was launched at 1323 hours CST, on May 17, 1961. During the flight, the rocket sustainer failed to separate from the payload; as a result, it descended without the aid of a parachute and disintegrated upon impact with the ground. Both rolls of film were recovered from the debris in the impact area but had torn loose from the camera magazines and were seriously damaged. The film was processed but very little information was obtained from the fragments of pictures that were legible.

No evidence was found from the payload fragments or telemetry data to indicate why the separation of payload from rocket did not occur.

NASA Rocket 1.06

Payload designated as Flight Unit 5 was flown on NASA Rocket 1.06. The rocket was launched at 1203 hours CST, May 19, 1961. All payload instrumentation except the parachute worked properly. The parachute was cut off in flight prior to opening instead of at impact.

The search helicopter received only weak signals from the SARAH transmitter and was unable to locate the payload on the day of launch. On May 20, the payload was sighted and recovered by the helicopter search teams (Figure 4); the SARAH batteries were discharged by the time the payload was found.

It was apparent that the payload had descended without a parachute and landed with a hard impact in a snow covered area. The hard impact did not damage the film in the cameras, but did damage the SARAH antenna; this probably caused the weakness of the transmitted signals.

The rolls of film recovered from the flights were processed by the United States Army. The following information is given concerning the cameras in NASA Rocket 1.06:

(1) Camera 3 was located in the aft payload position with a No. 12 filter and a polarizing filter. The aperture was set at f/4.5 with a shutter speed of 1/500 sec. Vignetting caused by the two camera filters starts at a diameter of 2.440 inches on the 2.25-inch-square negative. (Film from Camera 3 is referred to as Pola.)

(2) Camera 1 was located in the forward payload position with a No. 12 filter only. The aperture was set at f/8 with a shutter speed of 1/500 sec. (Film from Camera 1 is referred to as BW.)

(3) Both cameras contained SO 136 film (Kodak Experimental Panatomic-X Aerographic).

(4) Both cameras were programmed to start at T + 123 seconds and stop at T + 198 seconds.

(5) Camera 1 took 240 BW pictures, nine of which were looking up into the sky and contained no information for this test. Camera 3 took 228 Pola pictures, 12 of which were looking into the sky. Thus, there were 231 BW and 216 Pola pictures available for study.

(6) The rocket was rotating counterclockwise (looking aft) and took approximately 14 pictures per revolution. At a camera speed of 5 frames per second, the average spin rate is 0.36 rps.

PHOTOGRAPHIC RESULTS

A study of the Pola pictures (Figure 7) and the weather map (Figure 8) reveals that the Hudson Bay shore line running north from Churchill is easily identified. Button Bay, Churchill River, and the shore line running south from Churchill are visible through the clouds.

In determining whether there is any polarization effect in the pictures, it must be noted that a reduction in illumination from the center to the edge of the negative is characteristic of the lens-filter system employed. Therefore, what may appear to be a polarization effect from one frame to the next is, in most cases, due to reduced illumination because the subject area has changed position on the frame.

Because of the extreme cloud cover in the pictures, only one example of the polarization effect was discovered. Kaminak Lake, to the northwest of the western shore of Hudson Bay, illustrates the effect. The effect can be seen by studying frames 22, 106, and 216 from the Pola pictures (Figures 9, 10, and 11). The lake is quite visible in Figures 9 and 10, but disappears completely in Figure 11; Frame 15 from the BW pictures (Figure 12) is shown for comparison with Figure 9. By studying Figures 10 and 11 it can be seen that the camera orientations relative to the horizon was 90 degrees apart and the filter was evidently oriented so that the polarization effect was obtained.

At the time the pictures shown in Figures 10 and 11 were taken, the camera was pointing almost due north. The apparent declination of the sun was approximately 19.5 degrees. The peak altitude was approximately 45.4 miles. Table 2 gives times and altitudes for some of the pictures mentioned above. (The times were taken from telemetry records, and the altitudes are from previous AMPP trajectories.)

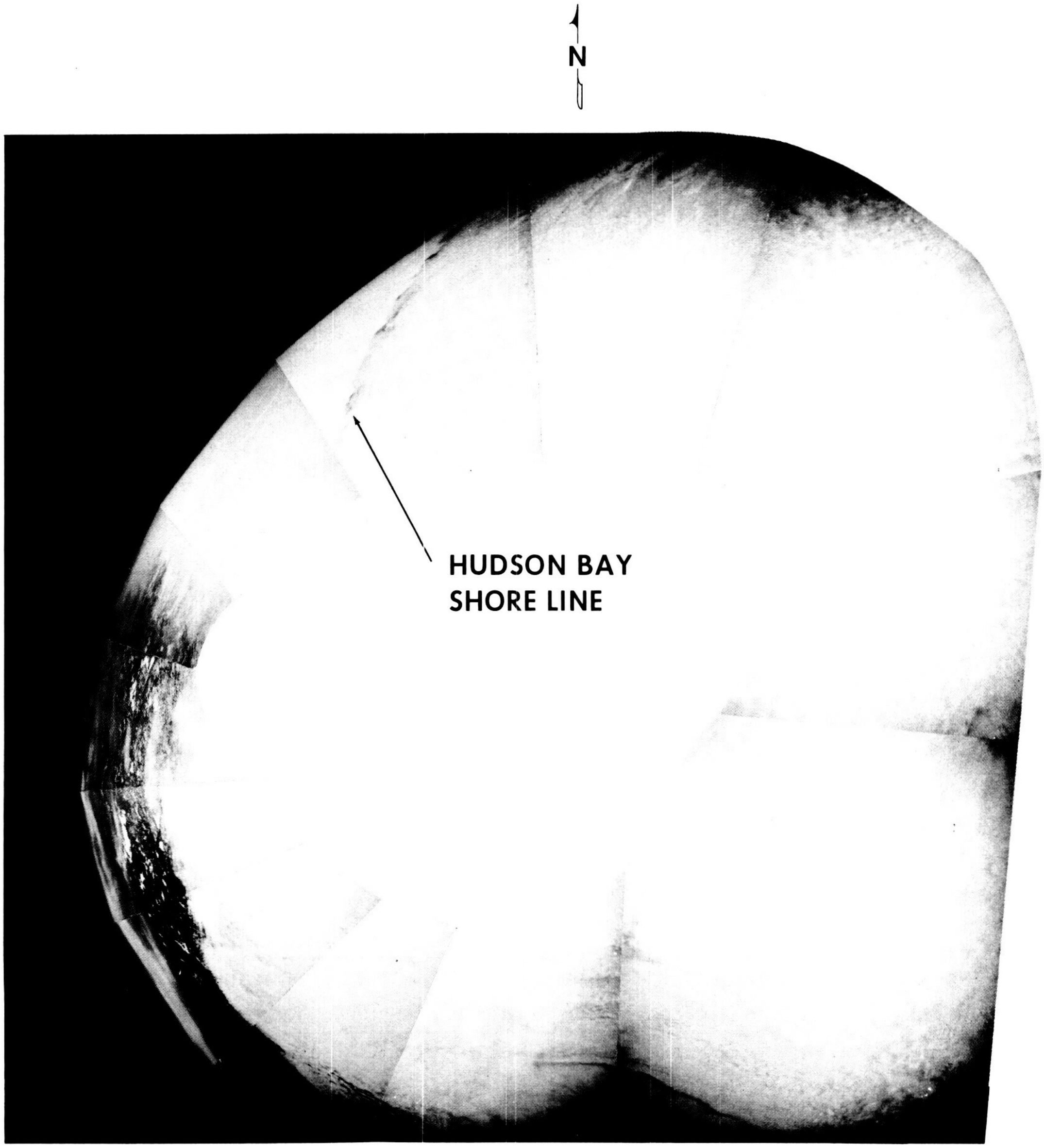
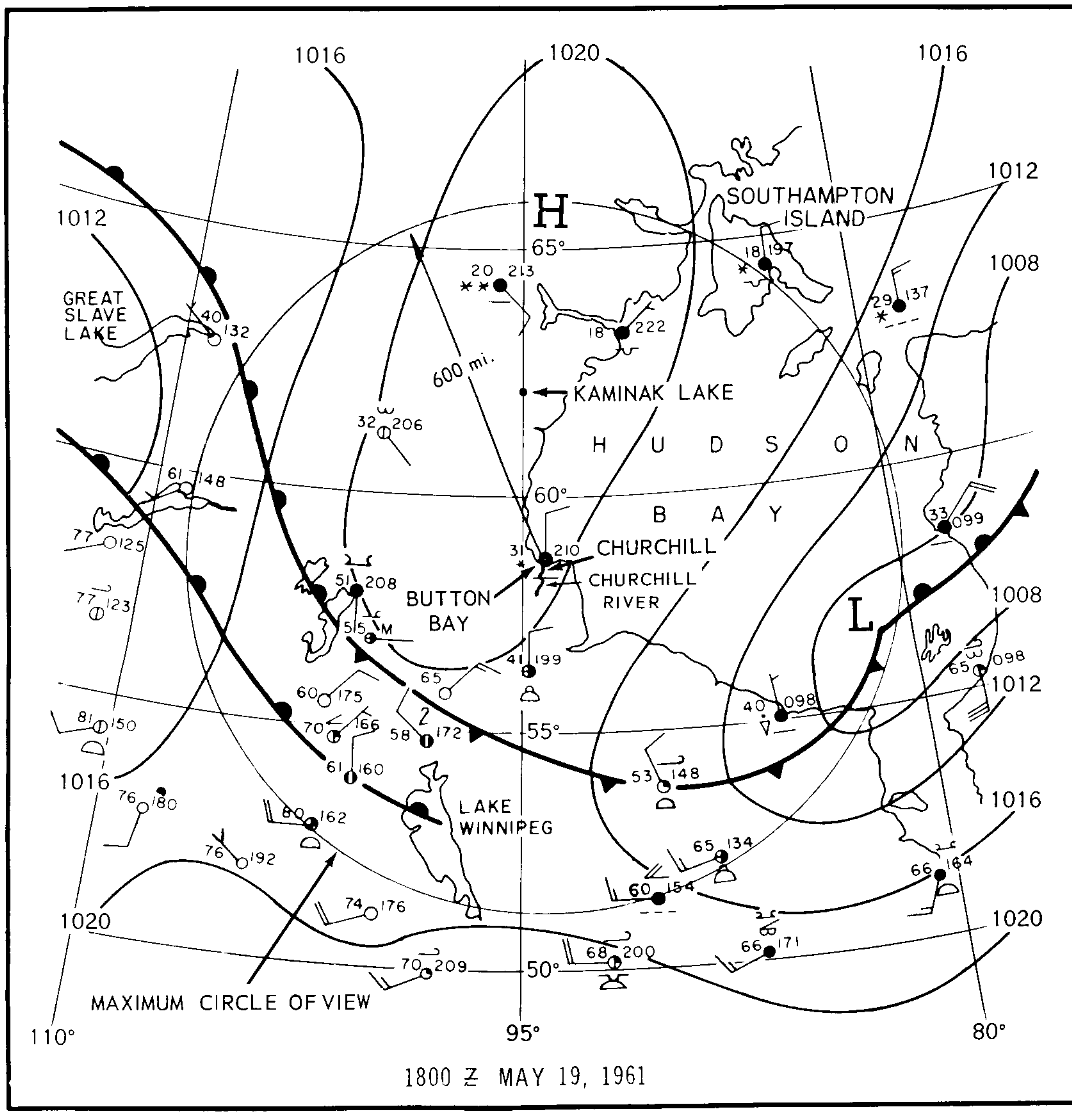


Figure 7—Composite of the area viewed by NASA Rocket 1.06.



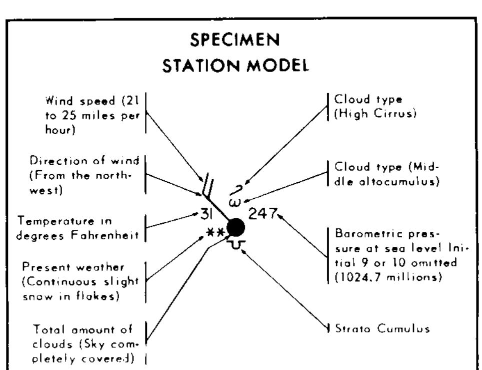


Figure 8—Weather map of the area viewed by NASA Rocket 1.06.

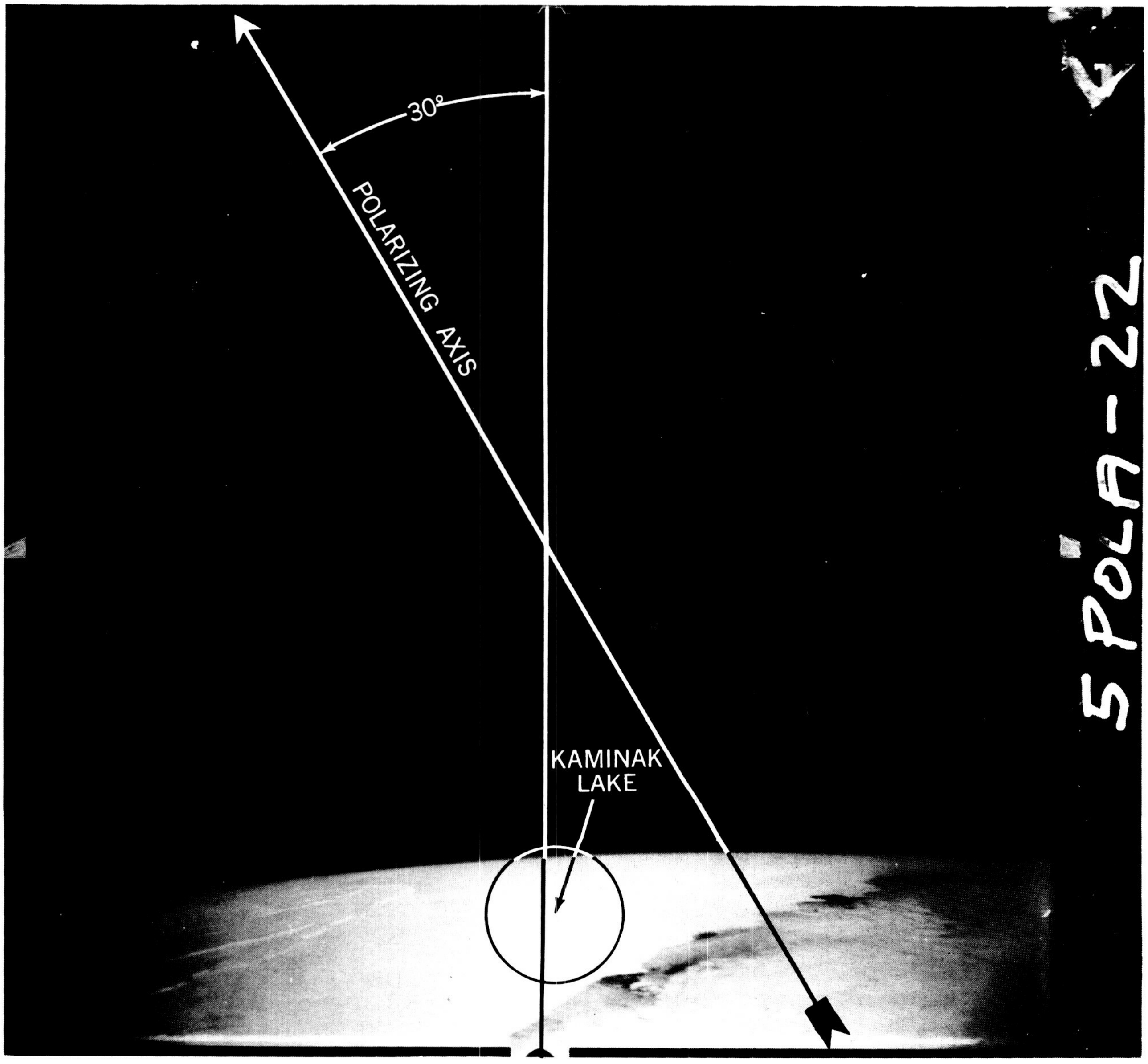


Figure 9—NASA Rocket 1.06 Frame 22 - photographed with polarizer.

TABLE 2

Altitude Versus Time of Figures 9, 10, 11, and 12.

Figure Number	Frame Number	Time from Liftoff (seconds)	Approximate Altitudes (statute miles)
9	Pola-22	136.9	45.25
12	BW-15	135.6	45.25
10	Pola-106	143.7	45.3
11	Pola-216	165.7	43.9

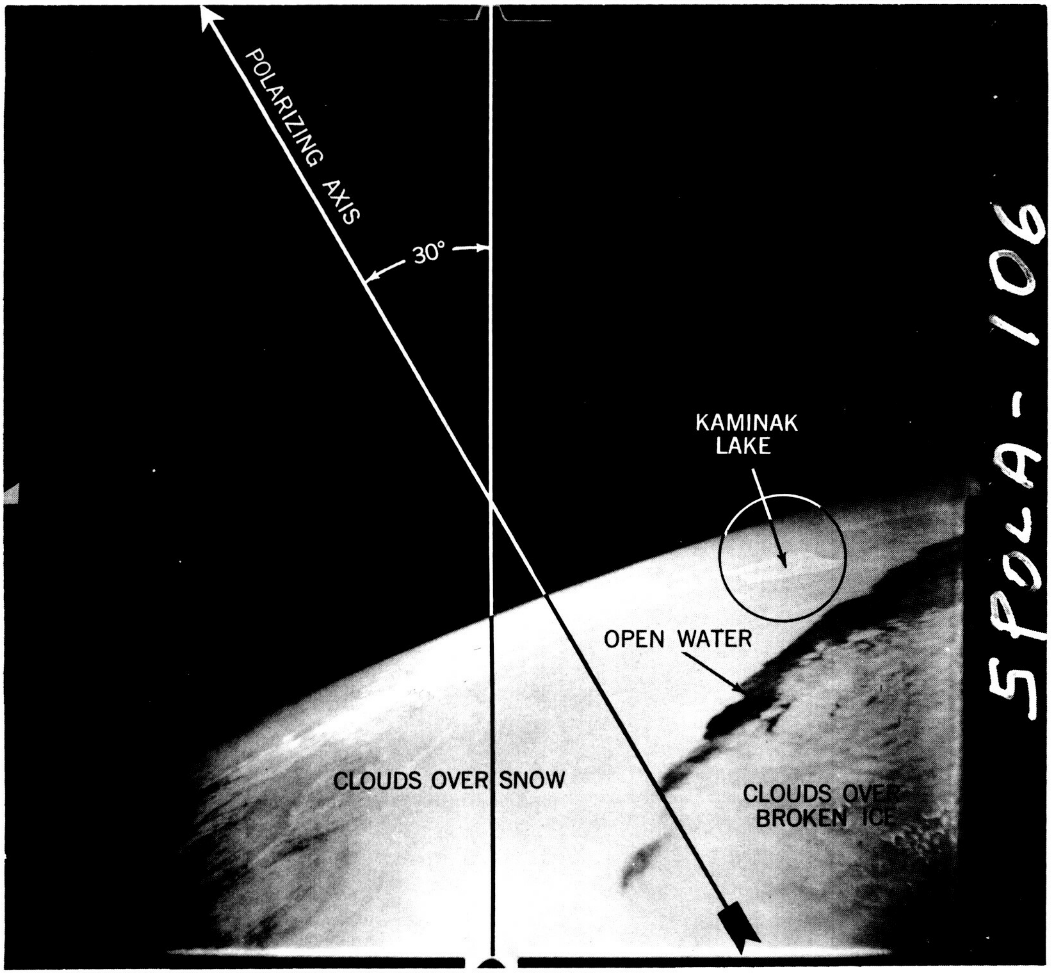


Figure 10—NASA Rocket 1.06 Frame 106 - photographed with polarizer.

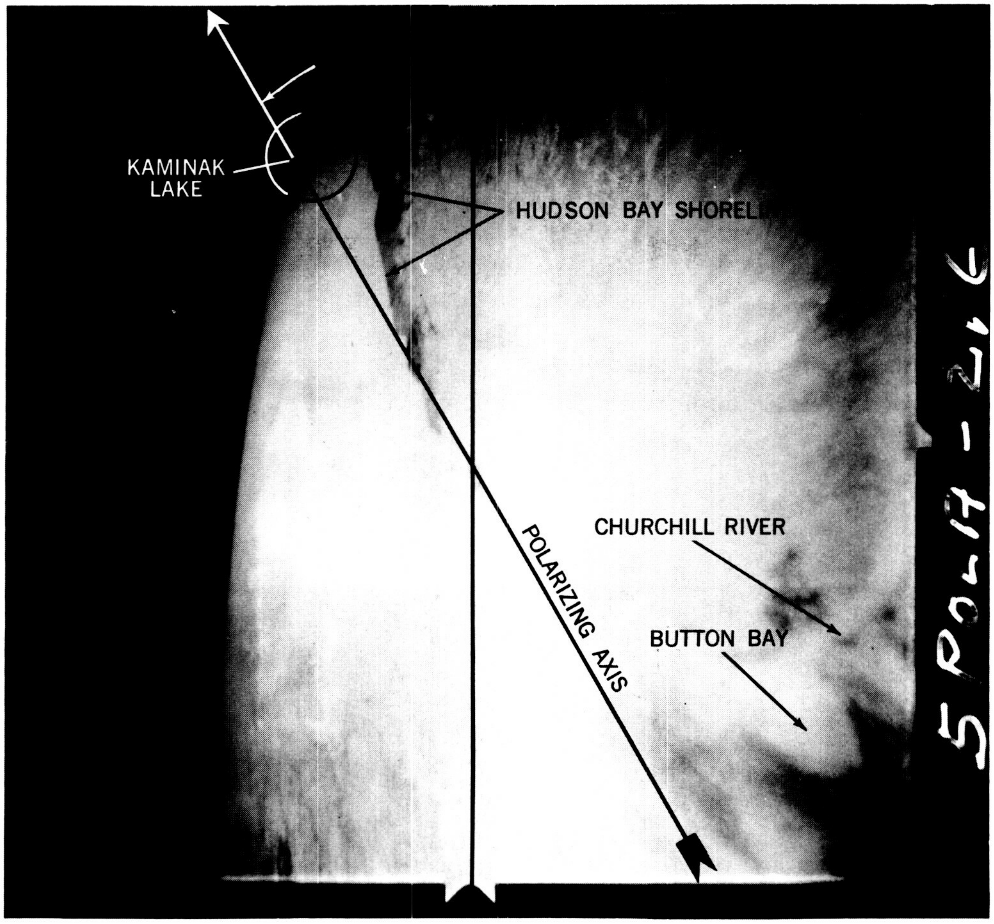


Figure 11—NASA Rocket 1.06 Frame 216 - photographed with polarizer.

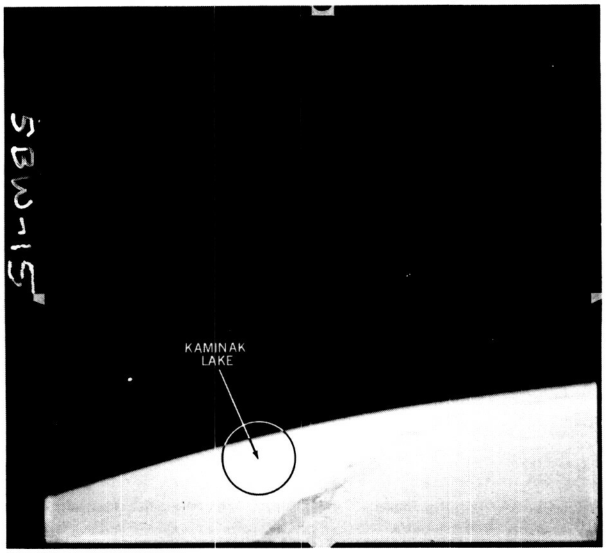


Figure 12—NASA Rocket 1.06 Frame 15 - photographed without polarizer.

CONCLUSIONS AND RECOMMENDATIONS

Limited information was obtained from the photographs but the polarizing effect is visible. The lack of information can be attributed to the severe cloud cover and incorrect film exposure as the lighting conditions changed with payload attitude. Also, the high stability of the payload did not allow a wide range of look angles at various subjects.

It would be desirable to use a camera system that automatically sets the aperture opening in flight to suit the various lighting conditions as the payload changes attitude.

Better information on the effectiveness of polarizers in helping to distinguish clouds from snow and ice may be obtained by using an infrared film in conjunction with a polarizer that is effective in the infrared region.

NASA-Langley, 1963 G-260